INDICATOR COPEPODS AND OIL YIELD FLUCTUATIONS IN PELAGIC FISH IN THE BENGUELA CURRENT SYSTEM

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(With 4 figures)

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ABSTRACT

The decline in the catches of the South West African pelagic fishery is paralleled by a declining trend in the oil yield (i.e. the ratio, fish oil to fish meal). Depressions in the oil yield show inverse correlation with the southward extension over the South West African shelf of a warm, saline water mass carrying the neritic copepods *Temora turbinata* and *Euterpina acutifrons*. In the region of north-west deflection of the Benguela waters, *T. turbinata* can be carried seaward over distances exceeding 250 nautical miles off shore.

Although fragmentary, the environmental data point towards a strong influence of abiotic factors on the abundance and condition of the available pelagic stocks.

CONTENTS

INTRODUCTION

Based initially on the pilchard (*Sardinops ocellata*), the South West African pelagic fishery once ranked among the most important in the world. From the middle sixties onward, a few short-lived depressions were experienced and from 1970, after the anchovy (*Engraulis capensis*) had become a regular component of the catches (up to 27% in 1970, increasing to 41% in 1973, according to official statistics), the total pelagic landings at Walvis Bay showed as spectacular a decline as their rise had been in the early sixties. Such a succession of events is not unique in the history of fisheries.

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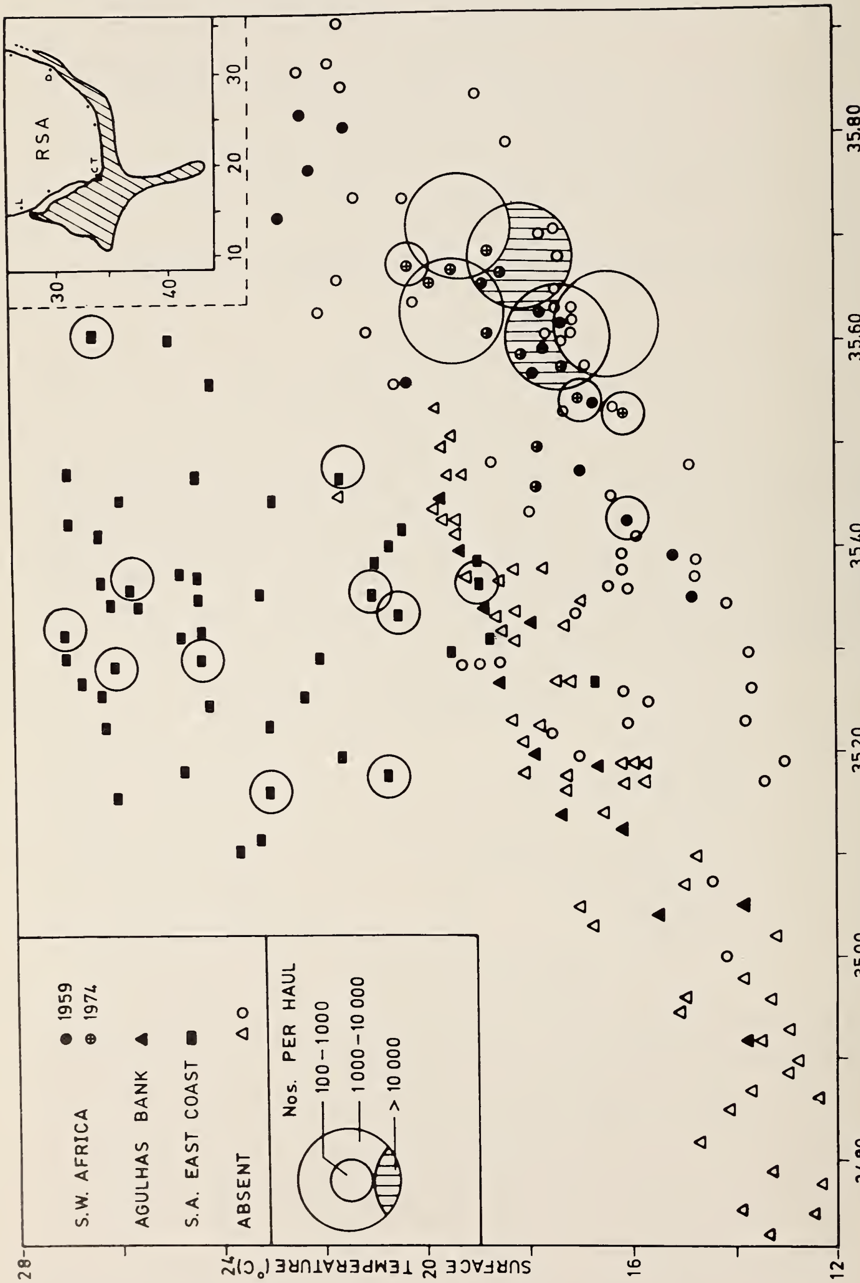


Fig. 1. T/S diagram of surface waters and occurrence of *Temora turbinata* around South and South West Africa. Inset: distribution of *T. turbinata* around South Africa.

The first serious alarm shook the local fisheries circles in 1963, when the oil yield of the pilchard missed its annual winter peak and stayed at minimum levels throughout the fishing season. Apart from this low oil yield, survey data revealed greatly reduced gonad development, virtual absence of eggs in the usual spawning grounds and abnormally high water temperatures and salinities. The plankton showed notable differences in density distribution and species composition from what Unterüberbacher (1964) had observed during a year-round monthly survey of the same area in 1961–2. Stander & De Decker (1969) attempted an interpretation of these physical and biological changes, using in the latter category what little is known about the biogeography of copepods in the south-eastern Atlantic.

Subsequent plankton studies in South West African waters indicated a correlation between the distribution and abundance of the copepod *Temora turbinata* and the annual oil yield cycle of the pelagic fish landings at Walvis Bay. These findings are the subject of the present report.

Temora turbinata is a neritic epipelagic copepod of tropical and subtropical waters of the Atlantic and Indo-Pacific where it is widespread and often predominant inshore. It has a wide salinity and temperature tolerance, but does not appear to subsist at temperatures below 15°C (Bradford 1977). Its distribution along the Atlantic coast of Africa is well documented through the work of a number of planktologists whose respective survey localities are spaced along the entire western coastline of the continent. An account of most of these contributions has been published by Thiriot (1977).

It appears to be present nearly everywhere in inshore waters, except where upwelling prevails, especially along the south-western and north-western coast. The contrast between the copepod assemblages in a habitat where *T. turbinata* predominates and one where it is excluded through upwelling is well illustrated by the examples of the Angolan neritic facies (Neto & De Paiva 1966) and the Walvis Bay area (Unterüberbacher 1964). In the former, 73% of the planktonic copepods consisted of *Oithona nana* (37%), *T. turbinata* (22%) and *Euterpina acutifrons* (14%), whereas the latter had 48% composed of *Centropages brachiatus* (18%), *Calanoides carinatus* (15%) and *Metridia lucens* (15%).

The full range of salinity and temperature records for *T. turbinata* around southern Africa is presented in Figure 1, based on the authors' unpublished data. The copepod adapts to the complete range of salinities prevailing in the various neritic environments encountered around the subcontinent, in temperatures between 14° and 28°C. Higher temperatures were not recorded in the neritic zone and it is, therefore, questionable whether 28°C is the upper limit for *T. turbinata*.

MATERIAL AND METHODS

The data discussed here were obtained from the following sources.

1. Survey Area A (see Fig. 2: April 1959). Nine quarterly surveys of a 240 nautical mile wide belt stretching from the Cape of Good Hope to Kunene

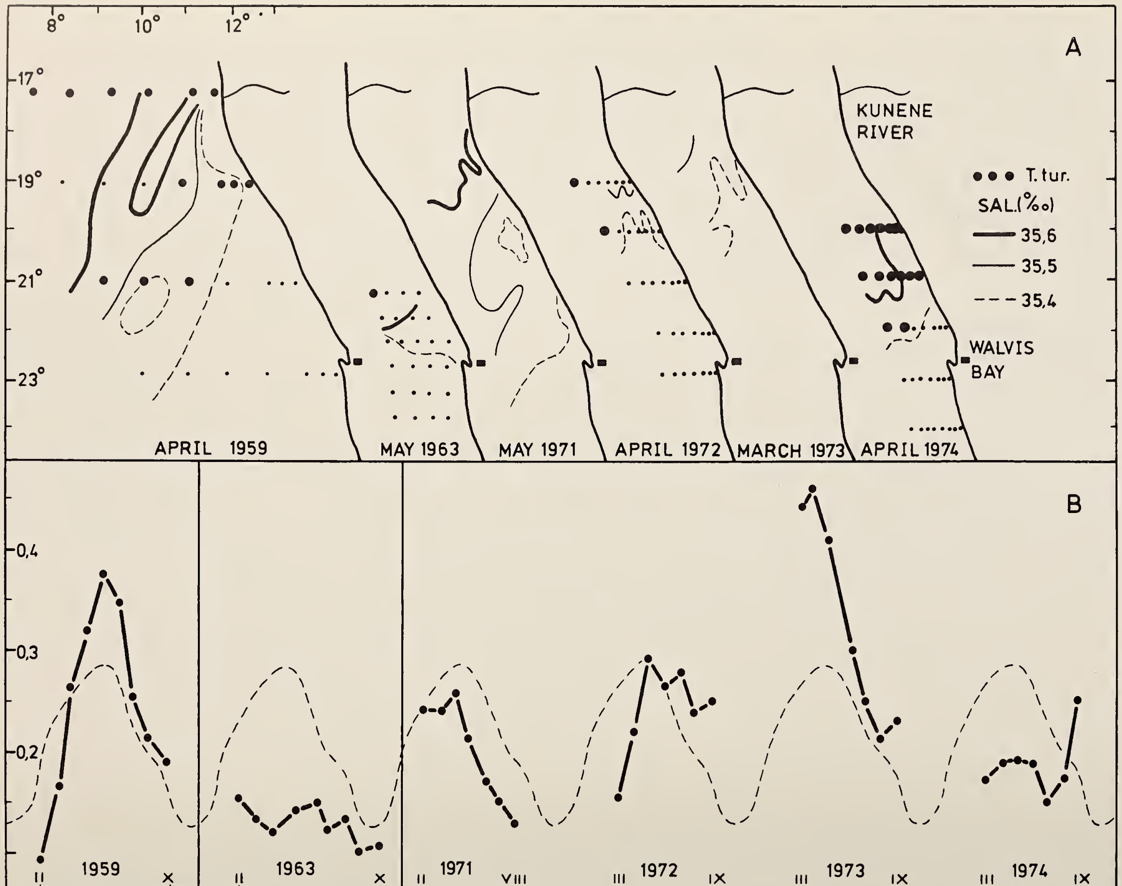


Fig. 2. A. Surface isohalines and occurrence of *Temora turbinata*. B. Oil yield fluctuations in pelagic catches (dotted line = average for 1965–1974).

River mouth (17°S) in January, April, July, October 1959, and January 1960, but to Ambrose Bay only (21°S) in April, July, October 1960, and January 1961. On these cruises, plankton was collected by means of a N70 net hauled vertically from 100 m to the surface—or bottom to surface where the sounding was less than 100 m. A total of 168 samples was examined.

2. Survey Area B (see Fig. 2: May 1963). Nineteen monthly surveys of a 90 nautical mile wide coastal belt between 21° and 24°S. The samples collected between April 1961 and March 1962 were studied by Unterüberbacher (1964) and those from December 1962 to August 1963 by Stander & De Decker (1969). The method of collection was the same as in Area A, and a total of 475 samples was examined.

3. Survey Area C (see Fig. 2: April 1972 to April 1974). A coastal belt of 50–70 nautical miles wide surveyed in the early seventies at irregular intervals and with varying station grids. The part stretching northward from Walvis Bay was examined for zooplankton taken on the following cruises: January, April, June, August and October 1972, and April 1974. A WP2 net was hauled vertically from a maximum depth of 200 m to the surface. A total of 108 samples was examined.

4. Statistics on pelagic fish landings at Walvis Bay and monthly oil yields from 1950 to 1977, except during closed seasons.

Areas A and C were surveyed by the Division of Sea Fisheries (later styled Sea Fisheries Branch, Cape Town), and Area B by the Marine Research Laboratory, Walvis Bay.

The plankton samples were examined under a stereomicroscope for identification and counting of species. Bulky samples were split to a convenient aliquot by means of a Folsom splitter, but the whole sample was then scanned for species not represented in the aliquot. The samples examined are housed in the plankton collections of the Sea Fisheries Branch, Cape Town.

Salinities in Areas A and B were estimated by the Knudsen method, in Area C by inductive salinometer, using water samples obtained with a Nansen Petterson bottle, which also provided the temperature readings.

RESULTS

Temora turbinata as an indicator

Although present in less than 5 per cent of the samples, *T. turbinata* drew the attention of both the present authors independently by its way of appearing suddenly in large numbers in a few samples, each time in the north of the survey areas. There is an indication of seasonality (January to May) which agrees reasonably with the peak of abundance of this species in Angolan waters (Neto & De Paiva 1966) and with the season of greatest activity of the Angola Current (Kuderski 1967).

The occurrences can be summarized as follows:

	Jan. '59	Apr. '59	May '63	Apr. '72	Apr. '74
Samples with *T. turbinata*	5	13	1	2	15
Total of specimens ..	32	853	1	6	174 400
N-limit of survey ..	17°S	17°S	21°S	19°S	20°S
S-limit of *T. turbinata* ..	19°S	21°S	21°S	20°S	22°S

The numbers of specimens caught on each occasion cannot be compared, due to the great differences in size and station spacing of the survey areas.

Salinity sections soon revealed that *T. turbinata* follows the 35,4‰ isohaline as it moves south and eastward into areas normally occupied by less saline waters typical of the Benguela system (Stander 1964). The waters with salinities in excess of 35,4‰ have a T/S diagram agreeing closely with that of the inshore station on the Angolan shelf off Lucira (13°51'S) monitored daily over a 4-year period (Berrit & Dias 1977) and fall within the range found in Baía Farta (12°36'S) by Neto & De Paiva (1966) and further south by Nümann (1953).

A plankton feature emphasizing the connection between Angolan shelf water and the saline water spreading *T. turbinata* over the whole width of the survey areas, is the presence of another dominant copepod of the Angolan shelf, *Euterpina acutifrons*. This species was unusually abundant in April 1974, when a total of 12 300 specimens was found at 14 stations distributed in a similar pattern to the 174 400 *T. turbinata* collected during that month. (Note: incidental attention only was given to *E. acutifrons* in the present context, because the likelihood of escapement of this small animal through the 200 μm meshes introduces an unknown bias in the catches. The *Oithonas* in our samples were not identified to species, therefore the presence or absence of *Oithona nana*, the most common copepod in Angola, has not been established.)

During the extensive surveys of January and April 1959, *T. turbinata* was found scattered offshore as far as the most distant stations, i.e. over 200 nautical miles beyond the shelf edge (Fig. 2). Very few instances could be found in literature where this neritic organism occurred at significant distances beyond the shelf. One is in the region of Dakar, where the Canaries Current curves away from the continent, with concomitant coastal upwelling: here Khromov (1973) found *T. turbinata* spread as far as 150 nautical miles offshore on one occasion. Another is in the Tasman Sea, where Bradford (1977) found it in large numbers in a sample taken 555 km (300 nautical miles) from the Australian coast in the path of a zonal jet originating from the East Australian Current. In a third example (from the authors' unpublished data), *T. turbinata* hugs the east coast of South Africa to East London, then fans out over the Agulhas Bank before spreading into the open Atlantic to about 35°S, 10°E (i.e. 360 nautical miles west of the Cape of Good Hope) but also follows the southward branch of the Agulhas Current as far as 43°S (i.e. 600 nautical miles due south of the Cape, staying all the way in salinities exceeding 35,45‰ and temperatures over 20°C (Fig. 1: inset).

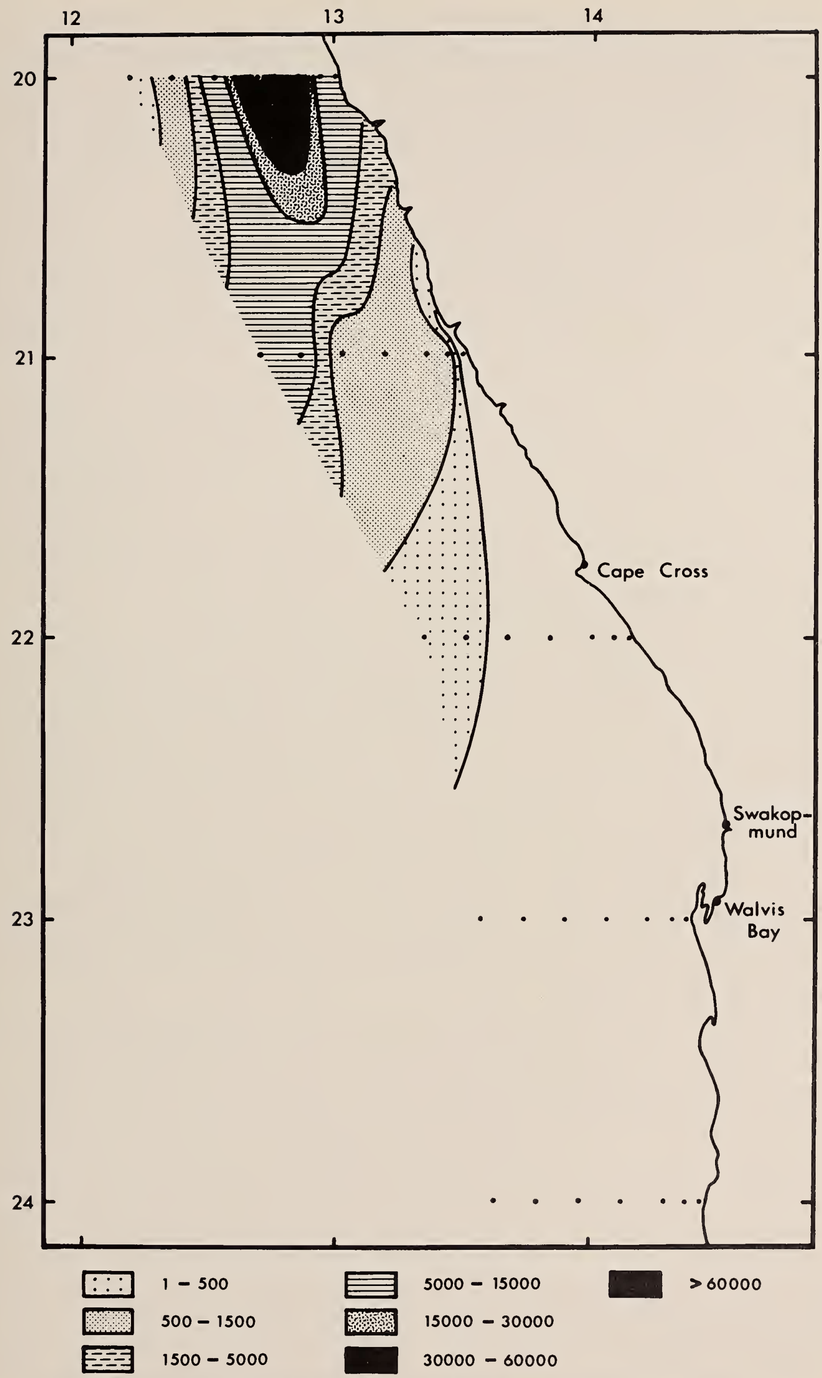


Fig. 3. Distribution of *Temora turbinata* (numbers/net haul) during April 1974.

The obvious indicator quality of *T. turbinata* may prove of practical value to physical and fisheries oceanographers in their attempts at interpreting the dynamics of the zone of interaction between the westward-curving Benguela Current and the water masses confronting it (Elizarov 1967; Kuderski 1967; Kornilova 1967; Moroshkin *et al.* 1970; Filippov & Kolesnikov 1971).

Oil Yield Fluctuations

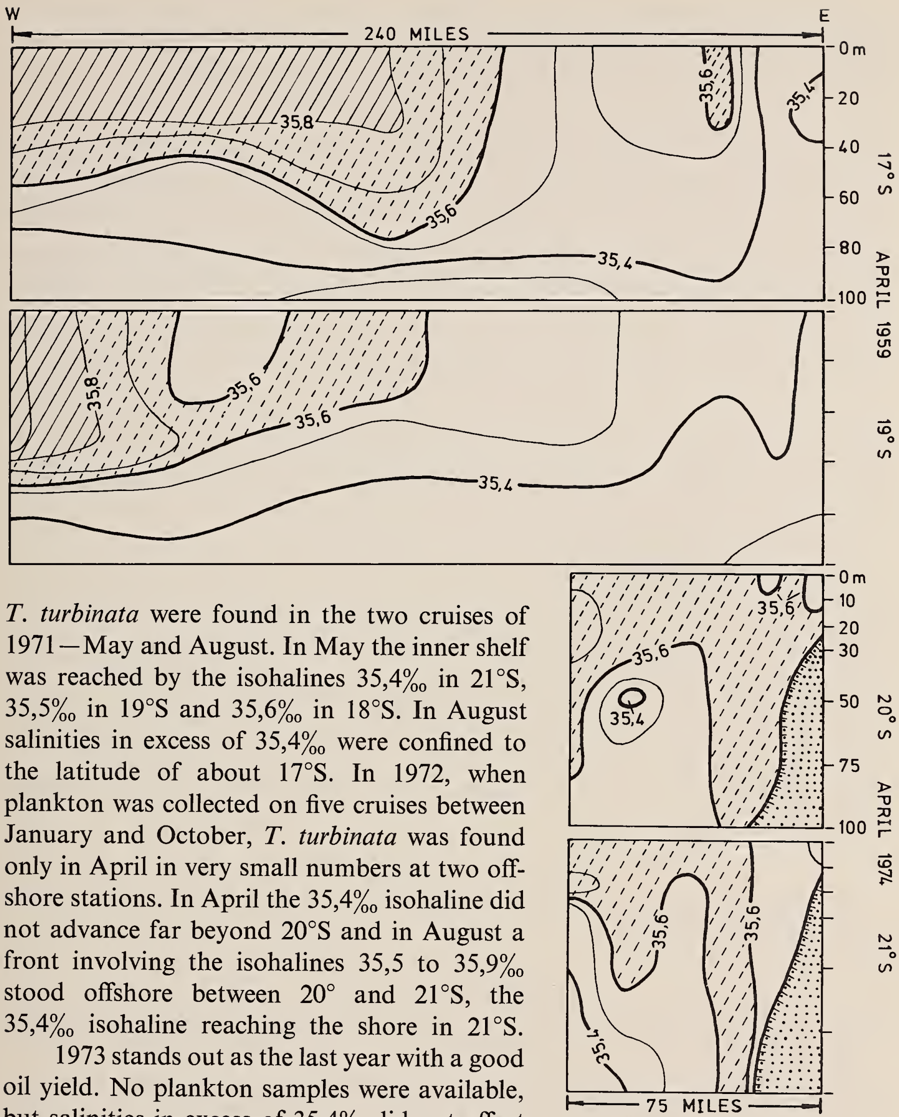
In spite of an unfortunate lack of continuity and uniformity in environmental monitoring of the South West African waters, especially during the critical years immediately before and during the decline of the pelagic fishery, the fragmentary data available show a parallelism between the environmental events and the vicissitudes of the pelagic stocks.

Arguing that the oil content of a fish gives a good indication of its physiological condition, Schülein (1976) has presented a diagram of the monthly oil yields of the pelagic fish landed at Walvis Bay between 1961 and 1974, later expanded to 1950–77 (pers. comm.). The oil yield is given as the ratio fish oil/fish meal (w/w), and plotted against the background of the average monthly oil yield for the period 1965–74. Excerpts from this diagram are used in Figure 2 to illustrate the correlation between the position of the isohalines, the presence/absence of *T. turbinata* and the oil yield in a number of cases.

During the oil yield depression of 1963 (Stander & De Decker 1969), already mentioned in the introduction, the height of the anomaly was characterized by a strong haline front (35,4–35,6‰) lying just inside the northern limit of the survey area in about 21°S. This front stood nearly vertically throughout the upper 50 m, separating a core of 20°C from Benguela water of 15°C and less. One single specimen of *T. turbinata* was found to the north of the front and overlooked in the discussion by Stander & De Decker, for obvious reasons. The 174 400 Temora found south of 20°S in April 1974 at 15 stations were a more obtrusive element (Figs 2–3), which caused us to compile all available records on *T. turbinata* in South West African waters and on thermohaline conditions in the area north of the latitude of Walvis Bay, regardless of the availability of concomitant plankton data.

During that April 1974 survey, the 35,4‰ isohaline reached as far south as 22°S, with that of 35,6‰ following in 21°20′S—no frontal condition by local standards. Two months earlier, however, in February, a strong front had suddenly appeared between 19°10′ and 19°30′S, bundling the isohalines from 35,4 to 35,9‰, the 35,4‰ isohaline reaching the shore in 20°S. In March the off-shore front had progressed southward to 23°S over nearly the whole width of the survey area, reaching the coast in 22°S. At the northern limit of the survey, Cape Frio (18°S), the near-shore salinity was 35,7‰. No plankton samples were available from February or March and our April samples were taken during the receding phase of the saline intrusion. The oil yield in 1974 was nearly as catastrophic as in 1963.

1971 and 1972 were on the lean side as far as oil yield is concerned. No



T. turbinata were found in the two cruises of 1971—May and August. In May the inner shelf was reached by the isohalines 35,4‰ in 21°S, 35,5‰ in 19°S and 35,6‰ in 18°S. In August salinities in excess of 35,4‰ were confined to the latitude of about 17°S. In 1972, when plankton was collected on five cruises between January and October, *T. turbinata* was found only in April in very small numbers at two offshore stations. In April the 35,4‰ isohaline did not advance far beyond 20°S and in August a front involving the isohalines 35,5 to 35,9‰ stood offshore between 20° and 21°S, the 35,4‰ isohaline reaching the shore in 21°S.

Fig. 4. Vertical sections of salinity for April 1959 and April 1974.

1973 stands out as the last year with a good oil yield. No plankton samples were available, but salinities in excess of 35,4‰ did not affect the inner shelf significantly further south than 19°S. This situation closely resembles the conditions prevailing in April 1959, i.e. a year with a good oil yield, although *T. turbinata* was present in significant numbers over a large area in the north (Fig. 2) but did not extend over the shelf beyond 19°S. The vertical sections in Figure 4 illustrate the difference in near-shore haline structure between a favourable year (1959) and an unfavourable one (1974).

The disastrous year 1974 was followed by three more years with minimal oil yield resembling that of 1963. Unfortunately, neither hydrological nor planktological data were available to the authors for that period.

CONCLUSIONS

To sum up, it appears that the yearly oil cycle of the available pelagic stocks in the South West African fishing ground correlates inversely with the volume and southward advance over the inner shelf of a water mass with salinities in excess of 35,4‰, which is related to, or identical with, the Angola Current. This water is marked by the presence of the copepod *Temora turbinata*—at least during the first half of the year.

According to Schülein's above-mentioned oil yield diagram for the period 1950–77, 13 consecutive years (1950–62) exceeded the 1965–74 oil yield average, with the only exception of 1957 which was slightly depressed. Then came the 1963 debacle followed by a spectacular upsurge in 1964, when an all-time record yield was reached. The subsequent 13-year period was marked by a steady decline, interrupted by peak years in 1968–70 and 1973, and ending with the 4 consecutive years of minimum yield mentioned above.

This downward trend of the oil yield (which cannot be explained to its full extent by the advent of the less oil-rich anchovy) is paralleled by the dramatic decline of the pelagic catches mentioned in the introduction. To look for a reason for this parallelism falls beyond the scope of the present communication. It is often difficult to establish to what extent the decline of a fishery is due to (over)fishing or to environmental change. In the present instance, however, it seems clear that the environment has played a primary role in the decline, its effects being aggravated by an exploitation policy that did not take the environmental stress into account.

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REFERENCES

Berrit, G. R. & Dias, C. A. 1977. Hydroclimatologie des régions côtières de l'Angola, Description des variations saisonnières à Lobito et Lucira. *Cah. ORSTROM, Océanogr.* **15** (2): 181–196.

Bradford, J. M. 1977. Distribution of the pelagic copepod *Temora turbinata* in New Zealand coastal waters, and possible trans-Tasman population continuity. *N.Z. Jl mar. freshw. Res.* **11**: 131–144.

Elizarov, A. A. 1967. Some results of oceanic research in fisheries areas off South West Africa. *Oceanology* **7**: 344–347.

Filippov, E. A. & Kolesnikov, G. I. 1971 (Origin of southward components in the Benguela Current system). *Trudy AtlantNIRO* **33**: 42–49.

Khromov, N. S. 1973 (Distributional features of some dominant copepod species in zones where the northern subtropical circulation of the Atlantic comes in contact with the coasts). *In: Bonitation of the World Ocean* **4**: 81–112 (Trudy VNIRO, 84).

Kornilova, G. M. 1967 (Characteristics of the plankton of the fishing grounds of the Eastern Atlantic in the spring of 1961). *Mater. Konfer. Result. okeanol. Issled. Atlant. Okeane,* AtlantNIRO: 158–171.

KUDERSKII, S. K. 1967. (Hydrology of the shelf waters off the South West African coast and its influence on the distribution and behaviour of certain commercial fish). *Mater. Konfer. Result. okeanol. Issled. Atlant. Okeane*, AtlantNIRO: 199–209.

MOROSHKIN, K. V., BUBNOV, V. A. & BULATOV, R. P. 1970. Water circulation in the Eastern South Atlantic. *Oceanology* **10**: 27–37.

NETO, T. S. & PAIVA, I. DE. 1966. Ciclo anual do zooplancton colhido na Baía Farta em 1960. *Notas mimeogr. Cent. Biol. aquat. trop.* **2**: 1–62.

NÜMANN, W. 1953. Campanhas em Angola. Estudos de química e física do meio marinho. *Trab. Miss. Biol. marít.* **1**: 33–66.

SCHÜLEIN, F. H. 1976. The relationship between recruitment and oil yields from pelagic fish. Paper presented at the First Interdisciplinary Conference on Marine and Freshwater Research in Southern Africa, Port Elizabeth, 5–10 July 1976. Mimeographed, 15 pp.

STANDER, G. H. 1964. The Benguela Current off South West Africa. *Investl Rep. mar. Res. Lab. S.W.Afr.* **12**: 1–43.

STANDER, G. H. & DE DECKER, A. H. B. 1969. Some physical and biological aspects of an oceanographic anomaly off South West Africa in 1963. *Investl Rep. Div. Sea Fish. Cape Town* **81**: 1–46.

THIRIOT, A. 1977. Peuplements zooplanctoniques dans les régions de remontée d'eau le long du littoral atlantique africain. *Docum. sci. Centre Rech. océanogr. Abidjan* **8**: 1–72.

UNTERÜBERBACHER, H. K. 1964. Zooplankton studies in the waters off Walvis Bay with special reference to the Copepoda. *Investl Rep. mar. Res. Lab. S.W.Afr.* **11**: 1–42.